ZooKeys 1172: 101–116 (2023)
DOI: 10.3897/zookeys.1172.105500

Research Article

Two new species of *Curvianchoratus* (Monogenoidea, Dactylogyridae) parasitizing *Psectrogaster amazonica* (Characiformes, Curimatidae) and a new record for *Curvianchoratus singularis* in the Tocantins River, Maranhão, Brazil

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Abstract

Several studies have demonstrated parasitism by monogenoids in characiform fish in the Neotropics. During studies on the helminth fauna of curimatids from the Tocantins River, specimens of *Psectrogaster amazonica* Eigenmann & Eigenmann, 1889 were examined and species of *Curvianchoratus* Hanek, Molnar & Fernando, 1974 were found. Species of the genus are characterized mainly by the complex shape of haptoral anchors with a modified dorsal anchor, composed by two subunits, dorsal-median and dorsal. To date, two species of *Curvianchoratus* are known to parasitize curimatid fishes: the type species *Curvianchoratus hexacleidus* Hanek, Molnar & Fernando, 1974 and *Curvianchoratus singularis* (Suriano, 1980). During examination of specimens of *P. amazonica* collected in the Tocantins River, Embiral, Imperatriz, Maranhão State, Brazil, two new species of *Curvianchoratus* were found and are described herein. *Curvianchoratus psectrogasteri* **sp. nov.** and *Curvianchoratus dominguesi* **sp. nov.** are characterized by possessing the male copulatory organ formed by a long cirrus and a claw-shaped accessory piece, connected to the base of the male copulatory organ by a ligament. The new species differs from the two known congeneric species mainly by the morphology of the dorsal-median and dorsal subunits of the dorsal anchor. *Curvianchoratus psectrogasteri* **sp. nov.** also differs from other species of the genus by the absence of the ventral bar and *Curvianchoratus dominguesi* **sp. nov.** by the size and shape of the ventral bar. An amendment to the diagnosis of *Curvianchoratus* is provided to accommodate the new species. The present study increases the number of *Curvianchoratus* species to four and extends the occurrence of the genus to the Tocantins-Araguaia Basin.

Key words: *Curvianchoratus dominguesi* sp. nov., *Curvianchoratus psectrogasteri* sp. nov., ectoparasites, fish parasite, helminth fauna, Neotropical Region, taxonomy, Tocantins-Araguaia Basin

OPEN ACCESS

Academic editor: Patrick M. Delgado
Received: 26 April 2023
Accepted: 26 May 2023
Published: 25 July 2023

ZooBank: https://zoobank.org/6A0A780E-B78B-4E54-9237-D01A82479F7B

Citation: Bezerra CAM, Cohen SC, de Meneses YC, Neres HGC, Viana DC, Justo MCN (2023) Two new species of *Curvianchoratus* (Monogenoidea, Dactylogyridae) parasitizing *Psectrogaster amazonica* (Characiformes, Curimatidae) and a new record for *Curvianchoratus singularis* in the Tocantins River, Maranhão, Brazil. ZooKeys 1172: 101–116. https://doi.org/10.3897/zookeys.1172.105500

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Introduction

Characiformes is one of the main orders of Ostariophysi, which occur exclusively in freshwater, with the greatest diversity and species richness concentrated in the Neotropical Region. These fish represent the historical connection between Africa and South America, which can be proven through their distribution and the presence of fossil records (Malabarba and Malabarba 2010, 2014). Among the families of the order, Curimatidae comprises eight extant genera and more than 110 species, living in diverse freshwater habitats from Costa Rica to Argentina (Melo et al. 2018).

Psectrogaster Eigenmann & Eigenmann, 1889 is a morphologically diverse lineage of Curimatidae, distributed in streams, rivers, and still waters throughout the drainage basins of the Orinoco River, Essequibo River, Amazon River, Paraguay-Parana River, and some of the rivers of northeastern Brazil (Vari 1989). *Psectrogaster amazonica* Eigenmann & Eigenmann, 1889, popularly known in Brazil as "branquinha" (Santos et al. 1984) is a freshwater fish that lives in tropical waters in the Tocantins and Amazon River basins (Vari and Röpke 2013; Froese and Pauly 2022). This species presents benthopelagic behavior, with the formation of large shoals, and has a maximum length of 19 cm, being one of the largest species of the genus (Vari 1989). The species is one of the most common and abundant along the Tocantins River in midwest, north and northeast Brazil and is the basis of an intensive fishery in this area. Individuals belonging to this species primarily feed on organic detritus, benthic organisms, and periphyton (Santos et al. 1984).

Several studies have demonstrated parasitism by monogenoids in Curimatidae fish in the Neotropics (Table 1). However, research involving the helminth fauna of *P. amazonica* is still incipient, with only two monogenoids described for this host so far (Freitas et al. 2021). Other studies regarding this fish species refer to larval development, the distribution of larvae in a natural breeding area, hematological parameters, and branchial histopathological alterations (Nascimento and Araújo-Lima 1993; Carvalho et al. 2009; Ponte et al. 2017; Bezerra et al. 2020; Pereira et al. 2020).

Monogenoidea Bychowsky, 1937 are, in general, ectoparasites that mainly infect fish species (Cohen et al. 2021). They have a simple and direct life cycle and, consequently, may present a high reproduction rate in these hosts (Lapera et al. 2017). Monogenoids are among the main components of the parasitic fauna of freshwater fish that occur in the Neotropics, most of them belonging to the family Dactylogyridae Bychowsky, 1933 (Cohen et al. 2013).

Curvianchoratus was proposed by Hanek, Molnar and Fernando (1974) to accommodate *Curvianchoratus hexacleidus* Hanek, Molnar & Fernando, 1974, a parasite of the characiform *Steindachnerina argentea* (Gill, 1858) (syn. *Curimatus argenteus* Gill, 1858) from the Arouca River, Trinidad. The main characteristic of *Curvianchoratus* is the haptor with a modified dorsal anchor, composed of two subunits, which is a unique shape within Dactylogyridae.

To date, two species of *Curvianchoratus* are known, both parasites of curimatid fishes: the type species *C. hexacleidus* and *Curvianchoratus singularis* (Suriano, 1980), originally described as *Notodiplocerus singularis* by Suriano (1980) parasitizing *Cyphocharax gilbert* (Quoy & Gaimard, 1824)

Table 1. Monogenoideans parasites of Curimatidae from South America.

Parasite	Host	Locality	References
Anacanthoroides mizellei Kritsky &Thatcher, 1976	*Steindachnerina insculpta*	Brazil	Acosta et al. (2013)
Annulotrematoides amazonicus Kritsky & Boeger, 1995	*Psectrogaster rutiloides*	Brazil	Kritsky and Boeger (1995)
Annulotrematoides bonaerensis Rossim & Timi, 2016	*Cyphocharax voga*	Argentina	Rossin and Timi (2016)
Cacatuocotyle paranaensis Boeger, Domingues & Kritsky, 1997	*Cyphocharax nagelii*	Brazil	Boeger et al. (1997), Vieira et al. (2013), Dias et al. (2017)
Characithecium chascomusensis (Suriano, 1981) Rossin & Timi, 2014	*Cyphocharax gilbert*	Argentina	Suriano (1981)
	C. voga		Suriano (1997)
Curvianchoratus hexacleidus Hanek, Molnar & Fernando, 1974	*Cyphocharax nagelii*	Brazil	Vieira et al. (2013)
Curvianchoratus singularis (Suriano, 1980) Suriano 1986	*C. gilbert*	Argentina	Suriano (1980)
	C. voga		Rossin and Timi (2016)
	Cyphocharax nagelii	Brazil	Vieira et al. (2013), Dias et al. (2017)
	Cyphocharax modestus		Dias et al. (2017)
	Steindachnerina insculpta		Dias et al. (2017)
Diaphorocleidus kabatai Mendoza-Franco, Reina & Torchin, 2009	*Stendachnerina insculpta*	Brazil	Acosta et al. (2013)
Euryhaliotrema chaoi Kritsky & Boeger, 2002	*Steindachnerina insculpta*	Brazil	Acosta et al. (2013)
Paranaella luquei Kohn, Baptista-Farias & Cohen, 2000	*Stendachnerina brevipinna*	Brazil	Ceschini et al. (2010)
Philocorydoras margolisi (Molnar, Hanek & Fernando, 1974) Yamada, Brandão, Yamada & Silva, 2015	*Steindachnerina insculpta*	Brazil	Dias et al. (2017)
Rhinoxenus guianensis Domingues & Boeger, 2005	*Curimata cyprinoides*	French Guyana	Domingues and Boeger (2005)
Urocleidoides curimatae Molnár, Hanek & Fernando, 1974	*Steindachnerina argentea*	Trinidad	Molnár et al. (1974)
Urocleidoides paratriangulus Freitas, Bezerra, Meneses, Justo, Viana & Cohen, 2021	*Psectrogaster amazonica*	Brazil	Freitas et al. (2021)
	Cyphocharax gouldingi		
Urocleidoides surianoae Rossim & Timi, 2016	*Cyphocharax voga*	Argentina	Rossin and Timi (2016)
Urocleidoides tocantinensis Freitas, Bezerra, Meneses, Justo, Viana & Cohen, 2021	*Psectrogaster amazonica*	Brazil	Freitas et al. (2021)
Urocleidoides triangulus (Suriano, 1981) Rossim & Timi, 2016	*C. nagelii*	Brazil	Vieira et al. (2013), Abdallah et al. (2015), Dias et al. (2017)
	Cyphocharax modestus		Abdallah et al. (2015), Dias et al. (2017)
	C. gilberti		Freitas et al. (2021)
		Argentina	Suriano (1981), Suriano (1997)

[syn. *Pseudocurimata gilbert* (Quoy & Gaimard, 1824)] from Argentina. Suriano (1986) transferred the parasite to *Curvianchoratus*. Rossin and Timi (2016) re-described this species from *Cyphocharax voga* (Hensel, 1870) from Argentina. In Brazil, *C. singularis* has been reported in the rivers of the state of São Paulo parasitizing Curimatidae fishes (Vieira et al. 2013; Dias et al. 2017).

During studies on the helminth fauna of curimatids from the Tocantins River, specimens of *P. amazonica* were examined and species of *Curvianchoratus* were found. The present paper presents an emended diagnosis of *Curvianchoratus*, with the proposal of two new species and a new geographical record for *C. singularis*.

Material and method

From July 2018 to April 2022, 136 samples of *P. amazonica* (average 14 cm in standard length and average 62 g in weight) were collected in the Tocantins River, close to the urban perimeter of Imperatriz, in the village of Embiral, state of Maranhão, Brazil (5°27'50"S, 47°33'48"W) (Fig. 1). Fish were caught with the aid of local fishermen using gill nets, or a hook and line and were examined asites immediately after capture at the Nucleus of Advanced Morphophysiological Studies at UEMASUL. The gills were removed and placed in vials containing hot water (65 °C) in order to detach the parasites from the gill filaments. Later, absolute ethanol was added to reach a concentration of 70%. Monogenoids were collected from the sediment and gill arches in the laboratory with the aid of a stereoscopic microscope. Specimens were mounted in Hoyer's medium to study the hard parts, such as the copulatory complex and haptoral sclerites and some were stained with Gomori's trichrome to study the internal organs of the parasite (Kritsky et al. 1978). Measurements are presented in micrometers; range values are followed by mean and number of structures measured in parentheses. Sclerotized structures, such as bars and anchors were measured according to the scheme shown in Fig. 2. The parasitological indices were calculated as proposed by Bush et al. (1997), followed by the standard deviation. The authorship of the taxa followed the recommendation of Article 50.1 of the International Code of Zoological Nomenclature (**ICZN**), which deals with the identity of the authors. The specimens were observed using an Olympus BX 41 microscope with phase contrast and Zeiss Axioskop 2 Plus microscope with

Figure 1. Map of Middle Tocantins River, showing the collection point of the hosts close to the urban perimeter of Imperatriz, in the village of Embiral, state of Maranhão, Brazil.

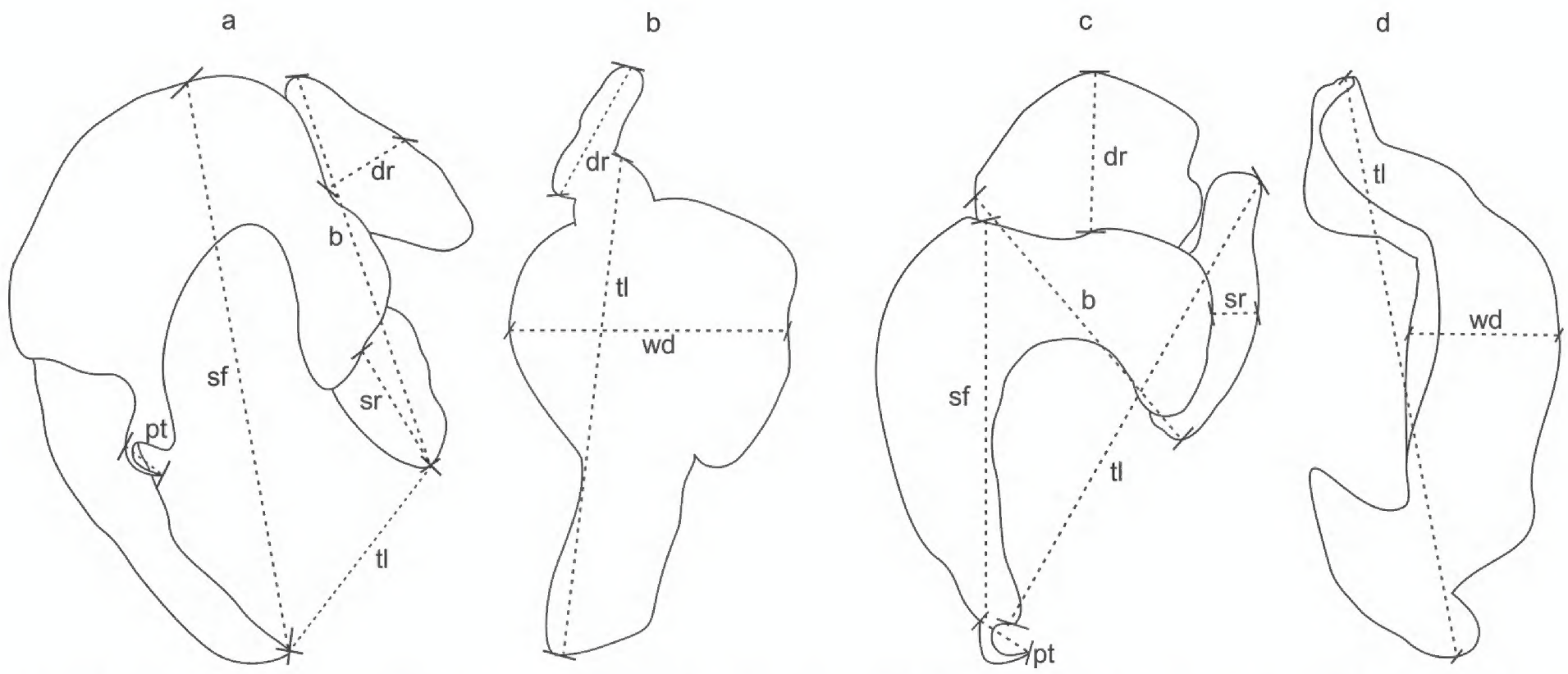

Figure 2. Scheme of measurements of the sclerotized structures of haptoral anchors of *Curvianchoratus* spp. **A** dorsal-median subunit and **B** dorsal subunit of *Curvianchoratus psectrogasteri* sp. nov. **C** dorsal-median subunit **D** dorsal subunit of *Curvianchoratus dominguesi* sp. nov. (sf) shaft, (pt) point, (dr) deep root, (sr) superficial root, (b) base, (tl) total length, (wd) width.

differential interference contrast, both equipped with a camera lucida for drawings. The images were captured with a SONY MPEG Movie EX DSC-S75 digital camera. Type specimens were deposited in the Coleção Helmintológica do Instituto Oswaldo Cruz (**CHIOC**) in Brazil.

Results

In the present study, a total of 87 monogenoid specimens were collected, being: 68 *Curvianchoratus psectrogasteri* sp. nov., eight *Curvianchoratus dominguesi* sp. nov. and 11 *Curvianchoratus singularis*.

Taxonomic account

Class Monogenoidea Bychowsky, 1937
Subclass Polyonchoinea Bychowsky, 1937
Order Dactylogyridea Bychowsky, 1937
Dactylogyridae Bychowsky, 1933

***Curvianchoratus* Hanek, Molnár & Fernando, 1974**

Emended diagnosis. Tegument smooth, thin. Body elongated; divisible into cephalic area, trunk, peduncle, and haptor. Terminal and lateral cephalic lobes developed or not; head organs and cephalic glands present. Eyespots present or absent. Mouth subterminal, midventral, prepharyngeal. Pharynx muscular; esophagus short. Intestinal caeca two, not presenting diverticula. Common genital pore midventral near the level of intestinal bifurcation. Gonads intercaecal, overlapping or not; testis dorsal to germarium. Seminal vesicle large, dilated portion of vas deferens; prostatic reservoir single. Copulatory complex comprising male copulatory organ (MCO) and accessory piece; MCO consisting of sclerotized coiled tube with counterclockwise rings, which make a short turn on itself

near the base; cirrus and accessory piece articulated basally. Accessory piece with bifurcated distal portion, pincer-shaped. Ovary pretesticular. Vagina medial or sinistral. Vitellaria well developed, coextensive with intestinal ceca, absent from regions of other reproductive organs. Peduncle short, haptor subquadrate. Ventral bar present or absent. Dorsal bar absent. Ventral anchor of dactylogyrid type. Dorsal anchor modified, composed by two subunits, dorsal-median and dorsal, forming a full circle, the shaft of the dorsal subunit passes over the superficial root of the dorsal-median subunit anchor. Hooks 14; 5 pairs ventral, 2 pairs dorsal, with inflated base and slender shank. Parasites of curimatid fishes.

Remarks. *Curvianchoratus* was proposed to accommodate *Curvianchoratus hexacleidus* Hanek, Molnár & Fernando, 1974, a parasite of the characiform *S. argentea* from the Arouca River, Trinidad (Hanek et al. 1974). The main characteristic of *Curvianchoratus* is the haptor with a modified dorsal anchor, composed of two subunits, which is a unique shape for the genus. The absence of bars in one of the species described here, made it necessary to expand the original diagnosis of the genus to include the characteristics of the new species described below, as well as to detail some morphological characters.

***Curvianchoratus psectrogasteri* Bezerra, Cohen, Meneses & Justo, sp. nov.**
https://zoobank.org/CB6BBC35-0D07-4EC8-A9E6-1BD568F8899B
Figs 3A–H, 5A, B, E

Type host. *Psectrogaster amazonica* Eigenmann & Eigenmann, 1889 (Curimatidae).

Type locality. Embiral, rural zone (5°27'50"S, 47°33'48"W), municipality of Imperatriz, Maranhão State.

Infestation parameters. 22.06% prevalence; 68 total number of parasites; 2.27 ± 1.75 mean intensity; 1-15 range of intensity.

Deposited material. ***Holotype*:** CHIOC 39977a; ***paratypes*:** CHIOC 39977 b-d, 39978 a, b, 39979, 39980, 39981, 39982.

Etymology. The specific name of the species is derived from the generic name of the host.

Description. Based on 43 specimens: 21 mounted in Gomori's trichrome and 22 mounted in Hoyer's medium: Body elongated, 425–883 (665; *N* = 30) long, 135–520 (308; *N* = 30) wide. Tegument smooth. Cephalic region with poorly-developed cephalic lobes; five pairs of head organs; cephalic glands lateral to pharynx. Eyes 4; anterior pair smaller than posterior. Pharynx round, muscular, 32–75 (50; *N* = 18) long, 32–87 (50; *N* = 18) wide; esophagus short. Peduncle inconspicuous, followed by a small haptor compared to body size, 125–292 (225; *N* = 21) wide. Ventral bar absent. Ventral anchor with inconspicuous deep root and elongated superficial root, long and slightly curved shaft; straight tip, not passing from the level of the tip of the superficial root, 21–30 (24; *N* = 43) long, base, 10–13 (12; *N* = 43) wide. Dorsal anchor complex heavily modified, composed by 2 subunits: dorsal-median and dorsal. Dorsal-median subunit strongly curved, 52–87 (64; *N* = 34) long and base, 41–63 (49; *N* = 48), with the robust shaft, 63–92 (78; *N* = 34) long, subdivided into two pieces, one anterior, with sclerotized ridges, and one posterior, lightly sclerotized, point sickle-shaped, articulated with the dorsal subunit, 4–7 (6; *N* = 36) long; deep and superficial roots well developed, crested-shaped, 12–27 (16; *N* = 46) long and 10–20 (14;

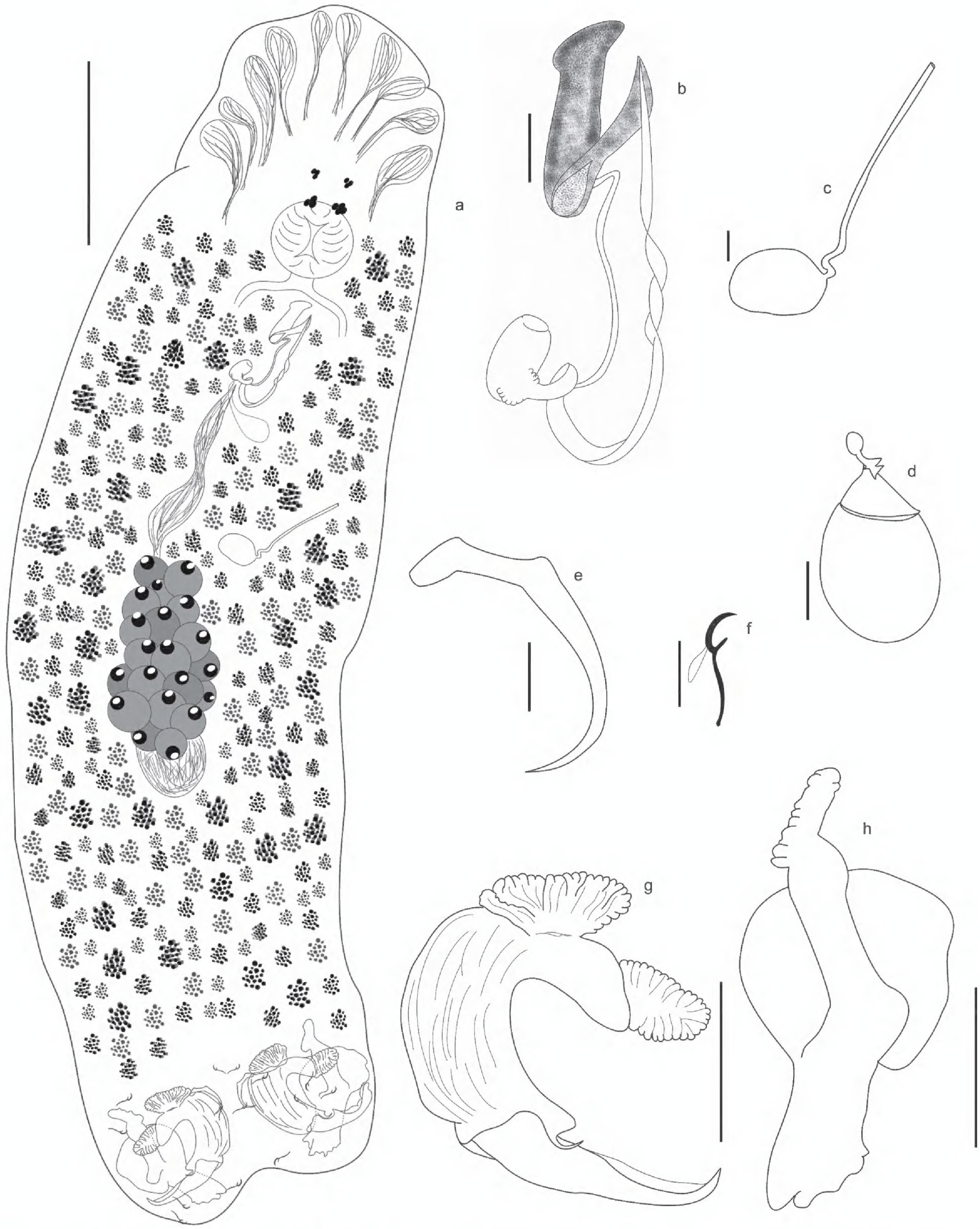

Figure 3. *Curvianchoratus psectrogasteri* sp. nov. from *Psectrogaster amazonica* from Tocantins River **A** whole specimen, ventral view **B** copulatory complex, ventral view **C** vagina **D** egg **E** ventral anchor **F** hook **G** dorsal-median subunit **H** dorsal subunit. Scale bars: 100 µm (**A**); 10 µm (**B, C, E, F**); 30 µm (**D, G, H**).

N = 37) long, respectively. Dorsal subunit large, irregular, 40–65 (48; *N* = 15) long well-developed deep root 19–22 (20; *N* = 17), superficial root absent, and median region expands to form a rounded structure, 32–57 (40; *N* = 23) wide. Hooks similar in shape, pairs 1 and 5 smaller than others, 11–14 (12; *N* = 27) long, pairs 2–4,6,7 with erected thumb, curved shaft, short point, shank with dilated bulb at distal end, 13–18 (16; *N* = 95). Copulatory complex comprising male copulatory

organ (MCO) and articulated accessory piece. Male copulatory organ composed by a tubular sclerotized cirrus that makes a short turn on itself near the base and spirals halfway towards the tip of the cirrus, with sclerotized base possessing delicate membrane, 47–60 (53; *N* = 5) in total length. Accessory piece, 25–30 (26; *N* = 5) long, claw-shaped, with dissimilar tip sizes, the smaller tip serves as guide to MCO, hinged by a ligament to the base of the cirrus. Testis oval, dorsal to germarium; seminal vesicle a distal enlargement of vas deferens; prostatic reservoir single, posterior to MCO. Germarium pretesticular, 62–122 (102; *N* = 7). Vaginal aperture midway between ovary and copulatory complex, sinistro-ventral, with vaginal canal slightly sclerotized, followed by rounded seminal receptacle, anterior to germarium. Oviduct, ootype, uterus not observed. Vitellaria dense, extends over the entire body, except in the region of the reproductive organs and haptor. Eggs operculated, 72–87 (82; *N* = 3) long by 60–70 (64; *N* = 3) wide.

Remarks. *Curvianchoratus psectrogasteri* sp. nov. is allocated in the genus mainly by the morphology of the copulatory complex, composed by a tubular cirrus and a pincer-shaped accessory piece, connected to the base of the cirrus by a ligament and by the presence of the greatly modified dorsal anchor, composed by two subunits: dorsal-median and dorsal. The new species differs from the two known species by the absence of the ventral bar and by the morphology of the dorsal-median subunit (strongly curved, with the shank and tip visibly separated; a robust shank ornamented with a thorn at the base and crested-shaped deep and superficial roots in the new species vs. a stickle shaped end inserted in the cavity of the shaft in *C. hexacleidus* and *C. singularis*) and by the morphology of the dorsal subunit (elongated, with a broadly circular central region in the new species vs. elongated, with deep root in *C. singularis* and without in *C. hexacleidus*).

***Curvianchoratus dominguesi* Bezerra, Cohen, Meneses & Justo, sp. nov.**
https://zoobank.org/E6B46BAD-9990-4E75-8781-D4DB18DE70D0
Figs 4A–G, 5C, D, F

Type host. *Psectrogaster amazonica* Eigenmann & Eigenmann, 1889 (Curimatidae).

Type locality. Embiral, rural zone (5°27'50"S, 47°33'48"W), municipality of Imperatriz, Maranhão State.

Infestation parameters. 5.15% prevalence; 8 total number of parasites; 1.14 ± 0.26 mean intensity; 1–2 range of intensity.

Deposited material. ***Holotype*:** CHIOC 39984; ***paratypes*:** CHIOC 39985, 39986, 39987, 39988, 39989.

Etymology. The specific name is in honor of Dr Marcus Vinicius Domingues for his contributions to the knowledge of neotropical monogenoidean fauna.

Description. Based on 7 specimens: 1 mounted in Gomori's trichrome and 6 mounted in Hoyer's medium: Body short, broad, 460–750 (575; *N* = 6) long, 225–500 (362; *N* = 6) wide. Tegument smooth. Cephalic region with 3 pairs of lateral lobes (two lateral and one terminal); five pairs of head organs; cephalic glands lateral to pharynx. Eyespots absent. Pharynx muscular, 50–63 (55; *N* = 3) long, 48–69 (58; *N* = 3) wide, esophagus short. Haptor small, compared to body size length, 400 (*N* = 2) wide. Ventral bar short and robust, anvil-shaped, with slightly jagged edges, 50–58 (52; *N* = 4) long. Ventral anchor with inconspicuous roots, shaft with two subunits, 25–32 (30; *N* = 5) long, with a short base, 11–17 (14; *N* =

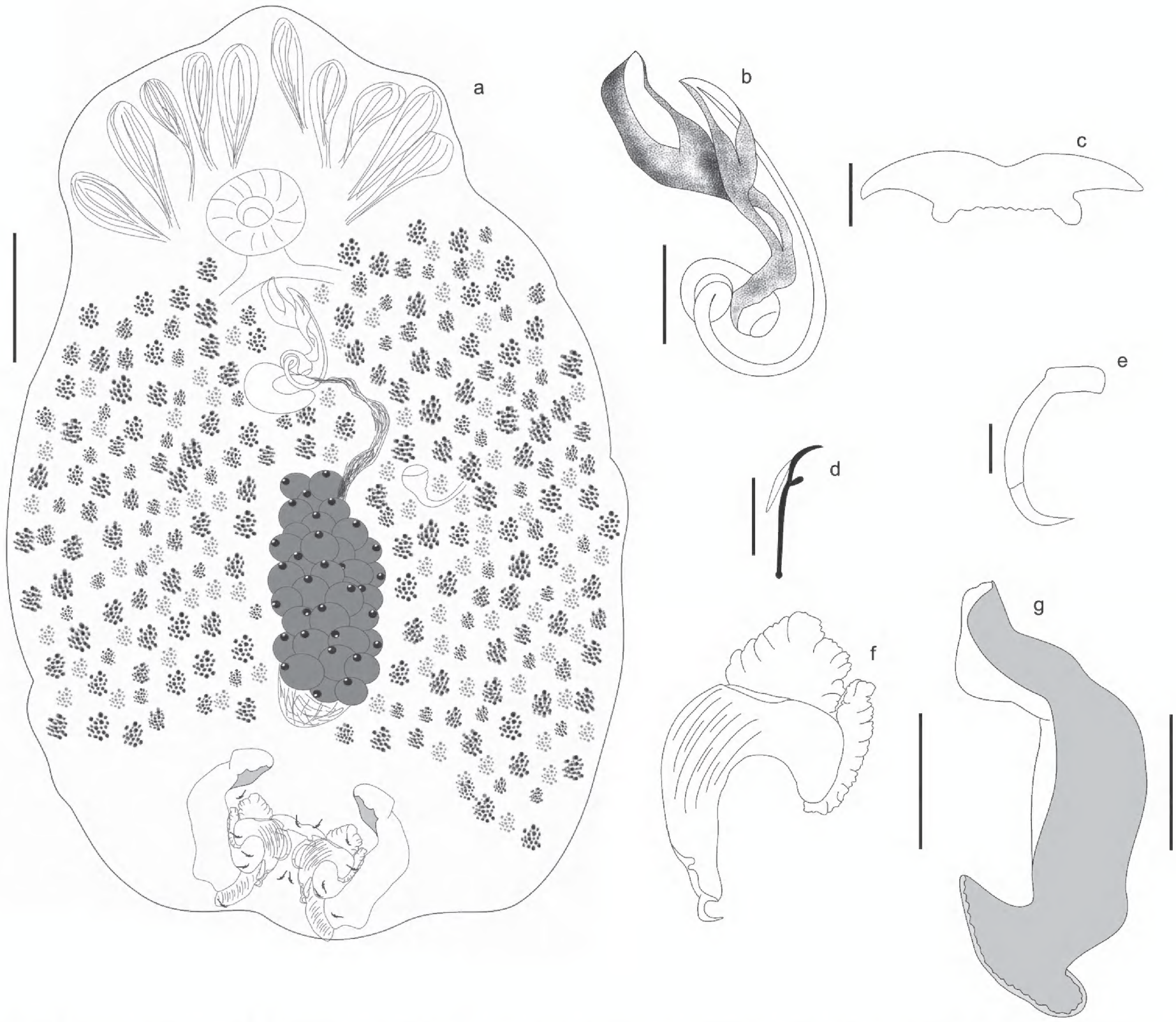

Figure 4. *Curvianchoratus dominguesi* n. sp from *Psectrogaster amazonica* from Tocantins River **A** whole specimen, ventral view **B** copulatory complex, ventral view **C** ventral bar **D** hook **E** ventral anchor **F** dorsal-median subunit **G** dorsal subunit. Scale bars: 100 µm (**A**); 30 µm (**B, F, G**); 10 µm (**C**–**E**).

5). Dorsal anchor complex heavily modified composed by 2 subunits: dorsal-median and dorsal. Dorsal-median subunit robust curved and heavily sclerotized, 50–66 (58; *N* = 13) long, shaft, 41–47 (44; *N* = 14); point as a robust hooked thorn, 6–10 (8; *N* = 14); superficial root, 5–8 (7; *N* = 3) and deep root, 13–17 (15; *N* = 6), well developed with borders very close to each other; point, 6–10 (8; *N* = 14). Dorsal subunit elongated, 65–100 (77; *N* = 9) long and 18–23 (19; *N* = 9) wide, 30% larger than the dorsal-median subunit, posterior portion fan-shaped. Hooks similar in shape, with erected thumb, curved shaft, and dilated bulb in the end, pair 1 smaller than the others, 11–12 (11; *N* = 4) long; pairs 2–7, 14–17 (16; *N* = 37). Copulatory complex comprising male copulatory organ and articulated accessory piece. MCO tubular, sclerotized, makes a short coil on itself, near the cirrus base, 55–75 (69; *N* = 4) in total length. Accessory piece claw-shaped, bifurcated, with different tip sizes; the smaller serves as a guide for the MCO, 42–70 (56; *N* = 5) long. Testis oval dorsal to the germarium; seminal vesicle formed by a distal enlargement of the vas deferens; prostatic reservoir single, in

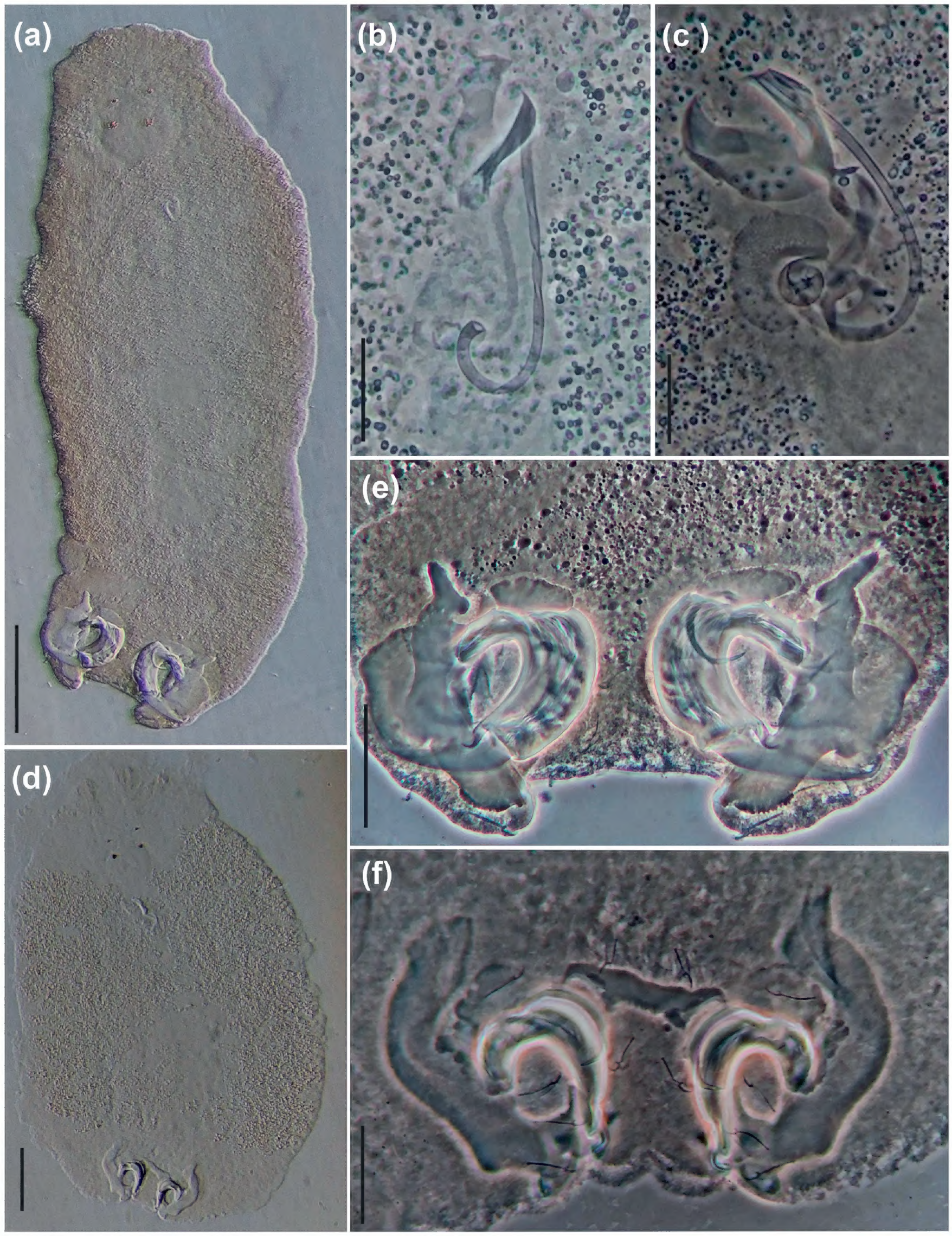

Figure 5. Light photomicrographs of *Curvianchoratus* spp. **A, B, E** *Curvianchoratus psectrogasteri* sp. nov. **A** total, ventral view **B** copulatory complex, ventral view **E** haptor **C, D, F** *Curvianchoratus dominguesi* sp. nov. **C** copulatory complex, ventral view **D** total, ventral view **F** haptor. Scale bars: 100 µm (**A**); 20 µm (**B**); 30 µm (**C, F**); 100 µm (**D**); 40 µm (**E**).

form of half-moon. Germarium pretesticular; seminal receptacle anterior to germarium; vaginal opening sinistro-ventral; vaginal canal wall sclerotized; oviduct, ootype, uterus, and eggs not observed. Vitellaria dense extends over the entire body, except in the region of the reproductive organs and haptor.

Remarks. *Curvianchoratus dominguesi* sp. nov. is similar to the other species of the genus mainly by the morphology of the dorsal anchor, the copulatory complex, which is composed by a long cirrus and a pincer-shaped accessory piece, connected to the base of the cirrus. The new species is similar to *C. singularis* and *C. hexacleidus* by the presence of the ventral bar. The new species differs from all congeneric species by the shape of the ventral anchor (formed by a shaft with two subunits in the new species vs. well-developed roots in *C. hexacleidus* and moderately developed deep root and well-developed superficial root in *C. singularis* and *C. psectrogasteri* sp. nov.), the morphology of the ventral bar (short and robust, anvil-shaped ventral bar in *C. dominguesi* sp. nov. vs. serpentine-shaped in *C. hexacleidus*, M-shaped in *C. singularis* and absent in *C. psectrogasteri* sp. nov.) and by the ratio of the subunits of the dorsal anchor (dorsal subunit is 30% larger than the dorsal-median subunit in *C. dominguesi* sp. nov. vs. the approximately same size of the subunits in the other three species of the genus).

***Curvianchoratus singularis* (Suriano, 1980) Suriano, 1986**

Notodiplocerus singularis Suriano, 1980. Syn.

Host. *Psectrogaster amazonica* Eigenmann & Eigenmann, 1889 (Curimatidae)

Site of infection. Gill.

Locality. Embiral, rural zone (5°27'50"S, 47°33'48"W), municipality of Imperatriz, Maranhão State.

Infestation parameters. 29.37% prevalence; 104 total number of parasites; 2,81 (±6,3) mean intensity; 1–38 range of intensity.

Type host and locality. *Cyphocharax gilbert* (syn. *Pseudocurimata gilbert*) from Chascomus Lagoon, Buenos Aires Province, Argentina (Suriano 1980).

Other records. *Cyphocharax voga* from Chascomus Lagoon, Buenos Aires Province, Argentina (Rossin and Timi 2016), *Cyphocharax modestus*, *Cyphocharax nagelii* and *Steindachnerina insculpta* from Batalha and Peixe Rivers, São Paulo State, Brazil (Vieira et al. 2013; Dias et al. 2017).

Specimens deposited. Voucher CHIOC 39990, 39991, 39992.

Remarks. Suriano (1980) described the species as *Notodiplocerus singularis* and the original drawings are simplified lacking important details of the morphology of these unique anchors that characterize the genus. In the description provided by Rossin and Timi (2016), the morphology of the dorsal anchor complex and copulatory complex was described in detail and illustrated by means of drawings and photographs. The morphology of the present material is in agreement with the material studied by Rossin and Timi (2016).

Discussion

Monogenoideans represent one of the main components of the helminth fauna present in freshwater fish in the Neotropics, most of which are dactylogyridean parasites of teleost fish (Boeger and Vianna 2006; Cohen et al. 2013; Braga et al. 2014). The great heterogeneity of hydrographic basins present in Brazil reflects a rich and diversified monogenoid fauna in this region (Tavares-Dias et al. 2022). Despite taxonomic efforts, the diversity of monogenoid parasites of

freshwater fishes from South America remains poorly known (Justo and Cohen 2019). According to Melo et al. (2018), most of the information regarding monogenoidean diversity in the Neotropical Region is limited to medium-sized fish species, while the parasitic fauna of small-sized species, especially Characiformes and Siluriformes, is not yet described.

Studies on the parasite diversity of freshwater fish from the Tocantins-Araguaia Basin have gradually increased in recent years [see Fehlauer and Boeger (2005); Boeger et al. (2006); Kritsky et al. (2007); Domingues and Marques (2011); Kritsky et al. (2013); Aguiar et al. (2017); Cárdenas et al. (2019, 2021, 2022); Cohen et al. (2020); Freitas et al. (2021)].

In this sense, the proposal of two new species of *Curvianchoratus* contributes to the knowledge of parasite fauna of the region and enlarges the morphological characters used to describe the unique species that ventral bar is absent (*Curvianchoratus psectrogasteri* sp. nov.), which is contrary to the known species of the genus. Although the presence of the bar is an important characteristic, we adopted a conservative approach when proposing a new species of this genus, because *C. psectrogasteri* exhibit the complex morphology of the dorsal anchor, characteristic of *Curvianchoratus*.

With the description of the two new species in the present study, *Curvianchoratus* now encompasses four species, all parasitizing curimatid fishes. *Curvianchoratus singularis* is herein reported in *P. amazonica* from the Tocantins River, expanding the occurrence of the species to the Tocantins-Araguaia Basin. The finding of three species of the genus in *P. amazonica* confirms the high specificity of the genus to neotropical curimatid hosts. On the other side, *Psectrogaster amazonica* harbors five monogenoidean species, two from a generalist monogenoidean genus, *Urocleidoides* (parasites from three different fish orders) (Freitas et al. 2021) and three from the specialist genus *Curvianchoratus*.

Additional information

Conflict of interest

No conflict of interest was declared.

Ethical statement

Permission to collect the hosts was given by the Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) through the Sistema de Autorização e Informação da Biodiversidade (SISBIO) under license number 79538-1.

Funding

Bezerra, CAM was supported by a doctoral scholarship Fundação de Amparo à Pesquisa e ao Desenvolvimento Científico e Tecnológico do Maranhão (FAPEMA) #154086/2021.

Author contributions

Conceptualization: SCC, MCNJ, CAMB. Formal analysis: SCC, MCNJ. Methodology: CAMB, HGCN, YCM. Project administration: DCV. Writing – original draft: CAMB. Writing – review and editing: SCC, MCNJ.

Carine Almeida Miranda Bezerra: Collected the hosts, and processed the methodology of collect of parasites; substantial contribution in the concept; contribution to data analysis and interpretation; contribution to manuscript preparation; Simone Chinicz Cohen:

Substantial contribution in the concept and design of the study; contribution to data analysis and interpretation; contribution to data collection; contribution to manuscript preparation; contribution to critical revision, adding intelectual content. Yuri Costa de Meneses: Processed the methodology to prepare of parasites; contribution to critical revision, adding intelectual content. Helyab Gabriel Chaves Neres Collected the hosts, and processed the methodology of collect of parasites. Diego Carvalho Viana: Project administration. Marcia Cristina Nascimento Justo: Substantial contribution in the concept and design of the study; contribution to data analysis and interpretation; contribution to manuscript preparation; contribution to critical revision; Writing original draft; prepared figures.

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Data availability

All of the data that support the findings of this study are available in the main text.

References

Abdallah VD, Azevedo RK, Silva RJ (2015) First record of *Palombitrema triangulum* (Suriano, 1981) Suriano, 1997 (Monogenea: Dactylogyridae) from freshwater fishes in Brazil. Brazilian Journal of Biology 75(1): 229–233. https://doi.org/10.1590/1519-6984.12913

Acosta AA, Queiroz J, Brandão H, Carvalho ED, Silva RJ (2013) Helminths of *Steindachnerina insculpta* in two distinct stretches of the Taqueri River, state of São Paulo, Brazil. Revista Brasileira de Parasitologia Veterinária 22(4): 539–547. https://doi.org/10.1590/S1984-29612013000400014

Aguiar JCC, Bueno GBF, Santos SMC, Adriano EA (2017) Supplementary taxonomic description of *Demidospermus pinirampi* (Monogenoidea, Dactylogyridae), with a new host record and an expansion of its distribution range. Acta Amazonica 47(4): 355–358. https://doi.org/10.1590/1809-4392201700112

Bezerra CAM, Sousa AL, Viana DC (2020) Histopathologic alterations of gill tissue in Siluriformes and Characiformes from the Middle Tocantins River in the Brazilian Amazon. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 72(1): 285–289. https://doi.org/10.1590/1678-4162-11467

Boeger WA, Domingues MV, Kritsky DC (1997) Neotropical Monogenoidea. 32. *Cacatuocotyle paranaensis* n.g., n.sp. (Dactylogyridae, Ancyrocephalinae) from *Characidium* spp. (Teleostei, Characidae) from the State of Parana, Brazil. Systematic Parasitology 36: 75–78. https://doi.org/10.1023/A:1005796027406

Boeger WA, Vianna RT (2006) Monogenoidea. In: Thatcher VE (Ed.) Amazon Fish parasites. Pensoft Publishers, Sofia, 42–116.

Boeger WA, Fehlauer KH, Marques EE (2006) Neotropical Monogenoidea. 49. Four new species of the Diplectanidae (Dactylogyrinea) from the gills of some pachyurines (Teleostei: Sciaenidae) from the Rio Tocantins and Rio Doce Basins, with proposal of *Anoplectanum* n.g. and *Spinomatrix* n.g. Systematic Parasitology 64(1): 57–68. https://doi.org/10.1007/s11230-005-9021-7

Braga MP, Araújo SBL, Boeger WA (2014) Patterns of interaction between Neotropical freshwater fishes and their gill Monogenoidea (Platyhelminthes). Parasitology Research 113(2): 481–490. https://doi.org/10.1007/s00436-013-3677-8

Bush AO, Lafferty KD, Lotz JM, Shostak W (1997) Parasitology Meets Ecology on Its Own Terms: Margolis et al. Revisited. The Journal of Parasitology 83(4): 575–583. https://doi.org/10.2307/3284227

Cárdenas MQ, Fernandes BMM, Justo MCN, Cohen SC (2019) A new species of *Ichthyouris* Inglis, 1968 (Nematoda: Pharyngodonidae) parasitizing two Characiform fishes from Tocantins River, Maranhão State, Brazil. Comparative Parasitology 86(1): 5–9. https://doi.org/10.1654/1525-2647-86.1.5

Cárdenas MQ, Justo MCN, Viana DC, Cohen SC (2021) New host record and geographical distribution of Nematoda parasitizing *Hypophthalmus marginatus* Valenciennes (Siluriformes) from the Tocantins River, Brazil. Acta Scientiarum. Biological Sciences 43: e58014. https://doi.org/10.4025/actascibiolsci.v43i1.58014

Cárdenas MQ, Justo MCN, Reyes ARP, Cohen SC (2022) Diversity of Nematoda and Digenea from different species of characiform fishes from Tocantins River, Maranhão, Brazil. Revista Brasileira de Parasitologia Veterinária 31(3): e005122. https://doi.org/10.1590/s1984-29612022038

Carvalho EG, Seibert CS, Coelho MS, Marques EE (2009) Parâmetros hematológicos de espécies nativas do rio Tocantins, *Auchenipterus nuchalis*, *Psectrogaster amazonica* e *Squaliforma emarginata* (Teleostei, Ostariophysi). Acta Scientiarum. Biological Sciences 31(2): 173–177. https://doi.org/10.4025/actascibiolsci.v31i2.1024

Ceschini TL, Takemoto RM, Yamada FH, Moreira LHA, Pavanelli GC (2010) *Paranaella luquei* (Monogenea: Microcotylidae), an ectoparasite from the gills of *Steindachnerina brevipinna*, in the tributaries Corvo and Guairaca, Paranapanema River, Parana, Brazil. Helminthologia 47(1): 29–32. https://doi.org/10.2478/s11687-010-0005-z

Cohen SC, Justo MCN, Kohn A (2013) South American Monogenoidea Parasites of Fishes, Amphibians and Reptiles. Conselho Nacional de Desenvolvimento Cientifico e Tecnologico (CNPq), 659 pp.

Cohen SC, Justo MCN, Gen DVS, Boeger WA (2020) Dactylogyridae (Monogenoidea, Polyonchoinea) from the gills of *Auchenipterus nuchalis* (Siluriformes, Auchenipteridae) from the Tocantins River, Brazil. Parasite 27(4): 1–12. https://doi.org/10.1051/parasite/2020002

Cohen SC, Cárdenas MQ, Justo MCN (2021) Checklist de Monogenoidea parasitos de peixes Siluriformes do Brasil. In: Melchior LAK, Meneguetti DUO, Camargo LMA, Oliveira J (Eds) Atualidades em Medicina Tropical na América do Sul: Veterinária (1st edn). Editora Stricto Sensu, 28–48. https://doi.org/10.35170/ss.ed.9786586283594.02

Dias KGA, Vieira DHMD, Camargo AA, Silva RJ, Azevedo RK, Abdallah VD (2017) Diversity of monogeneans from Characiformes fishes in the Batalha River and Peixe's River, state of Sao Paulo, Brazil. Neotropical Helminthology 11(12): 317–330.

Domingues MV, Boeger WA (2005) Neotropical Monogenoidea. 47. Phylogeny and coevolution of species of *Rhinoxenus* (Platyhelminthes, Monogenoidea, Dactylogyridae) and their Characiformes hosts (Teleostei, Ostariophysi) with description of four new species. Zoosystema 27(3): 441–467.

Domingues MV, Marques FPL (2011) Phylogeny and taxonomy of *Potamotrygonocotyle* Mayes, Brooks, Thorson, 1981 (Monogenoidea: Monocotylidae) with a description of four new species. Journal of Helminthology 85(4): 353–380. https://doi.org/10.1017/S0022149X10000684

Fehlauer KH, Boeger WA (2005) Neotropical Monogenoidea: *Euryhaliotrema dontykoleos* sp. nov. (Dactylogyridae) from the gills of the freshwater sciaenid, *Pachyurus*

junki (Perciformes). The Journal of Parasitology 91(5): 1025–1027. https://doi.org/10.1645/GE-486R.1

Freitas AJB, Bezerra CAM, Meneses YC, Justo MCN, Viana DC, Cohen SC (2021) Three new species of *Urocleidoides* (Monogenoidea: Dactylogyridae) parasitizing characiforms (Actinopterygii: Characiformes) in Tocantins River, states of Tocantins and Maranhão, and new record for *U. triangulus* in Guandu River, state of Rio de Janeiro, Brazil. Zoologia 38: e65001. https://doi.org/10.3897/zoologia.38.e65001

Froese R, Pauly D [Eds] (2022) FishBase. World Wide Web electronic publication. www.fishbase.org, version (08/2022). [Accessed on 5 April 2022]

Hanek G, Molnár K, Fernando CH (1974) Three new genera of Dactylogyridae (Monogenea) from freshwater frishes of Trinidad. The Journal of Parasitology 60(6): 911–913. https://doi.org/10.2307/3278510

Justo MCN, Cohen SC (2019) Monogenoidea: Implicações na aquicultura e revisão das principais alternativas de tratamento. In: Ranzani-Paiva MJT, Takemoto RM, Lizama MAP, Perazzolo LM, Rosa RD (Eds) Biotecnologia e Sanidade de Organismos Aquáticos. Abrapoa, São Paulo, 371–398.

Kritsky DC, Boeger WA (1995) Neotropical Monogenoidea. 26. *Annulotrematoides amazonicus*, new genus and species (Dactylogyridae: Ancyrocephalinae), from the gills of *Psectrogaster rutiloides* (Kner) (Teleostei: Characiformes: Curimatidae) from the Brazilian Amazon. Proceedings of the Biological Society of Washington 108(3): 528–532. https://www.biodiversitylibrary.org/part/44854

Kritsky DC, Boeger WA, Mendoza-Franco EF, Vianna RT (2013) Neotropical Monogenoidea. 57. Revision and phylogenetic position of *Scleroductus* Jara & Cone, 1989 (Gyrodactylidae), with descriptions of new species from the Guatemalan Chulin *Rhamdia guatemalensis* (Günther) (Siluriformes: Heptapteridae) in Mexico and the barred sorubim *Pseudoplatystoma fasciatum* (Linnaeus) (Siluriformes: Pimelodidae) in Brazil. Systematic Parasitology 84: 1–15. https://doi.org/10.1007/s11230-012-9387-2

Kritsky DC, Leiby PD, Kayton RJ (1978) A rapid stain technique for the haptoral bars of *Gyrodactylus* species (Monogenea). The Journal of Parasitology 64(1): 172–174. https://doi.org/10.2307/3279642

Kritsky DC, Vianna RT, Boeger WA (2007) Neotropical Monogenoidea. 50. Oviparous gyrodactylids from loricariid and pimelodid catfishes in Brazil, with the proposal of *Phanerothecioides* n. g.; *Onychogyrodactylus* n. g. and *Aglaiogyrodactylus* n. g. (Polyonchoinea: Gyrodactylidea). Systematic Parasitology 66(1): 1–34. https://doi.org/10.1007/s11230-006-9053-7

Lapera IM, Silva AC, Canônico BM, Perezin GF, Tebaldi JH, Pala G, Manrique WG, Hoppe EGL (2017) Metazoan parasites of *Plagioscion squamosisimus*, an invasive species in the Tietê River, São Paulo, Brazil. Revista Brasileira de Parasitologia Veterinária 26(2): 143–151. https://doi.org/10.1590/s1984-29612017035

Malabarba MC, Malabarba LR (2010) Biogeography of Characiformes: an evaluation of the available information of fossil and extant taxa. In: Nelson JS, Schultze HP, Wilson MVH (Eds) Origin and Phylogenetic Interrelationships of Teleosts. Verlag Dr. Friedrich Pfeilp, Munique, 317–336.

Malabarba L, Malabarba MC (2014) Filogenia e classificação dos peixes Neotropicais. In: Baldisserotto B, Cyrino JEB, Urbinati EC (Eds) Biologia e Fisiologia de Peixes Neotropicais de Água Doce. FUNEP, Jaboticabal, 12 pp.

Melo BF, Sidlauskas BL, Hoekzema K, Vari RP, Dillman CB, Oliveira C (2018) Molecular phylogenetics of Neotropical detritivorous fishes of the family Curimatidae (Teleostei:

Characiformes). Molecular Phylogenetics and Evolution 127: 800–812. https://doi.org/10.1016/j.ympev.2018.06.027

Molnár K, Hanek G, Fernando CH (1974) Ancyrocephalids (Monogenea) from freshwater fishes of Trinidad. The Journal of Parasitology 60(6): 914–920. https://doi.org/10.2307/3278511

Nascimento FL, Araújo-Lima C (1993) Descrição das larvas de *Psectrogaster amazonica* e *Potamorhina altamazonica* (Curimatidae, Pisces) da Amazonia central. Acta Amazonica 23(4): 457–472. https://doi.org/10.1590/1809-43921993234472

Pereira NJ, Santos MM, Maião JPLS, Campos JSP, Silva ND, Mendes DCS, Lenz TM, Santos DMS (2020) Biomarcadores histológicos em brânquias de peixes na avaliação da contaminação ambiental do Rio Mearim, Nordeste brasileiro. Journal of Development 6(8): 56600–56616. https://doi.org/10.34117/bjdv6n8-175

Ponte SCS, Silva AJS, Zacardi DM (2017) Áreas de dispersão e berçário para larvas de Curimatidae (Pisces, Characiformes), no trecho baixo do rio Amazonas, Brasil. Interciencia 42(11): 727–732. https://www.redalyc.org/journal/339/33953499004/html/

Rossin MA, Timi JT (2016) Dactylogyrid monogeneans parasitising *Cyphocharax voga* (Hensel) (Teleostei: Curimatidae) from the Pampas region, Argentina: new and previously described species. Systematic Parasitology 93(7): 701–714. https://doi.org/10.1007/s11230-016-9654-8

Santos GM, Jegu M, Merona B (1984) Catálogo de Peixes Comerciais do Baixo rio Tocantins (1st ed.). Projeto Tucuruí, Eletronorte, INPA, Manaus, 82 pp.

Suriano DM (1980) *Notodiplocerus singularis* gen. et sp. nov. (Monogenea Ancyrocephalinae) parasita de las branquias de *Pseudocurimata gilbert* (Pisces Tetragonopteridae) de la laguna de Chascomus, República Argentina. Neotrópica 26: 131–142.

Suriano DM (1981) *Androspira* gen. n. (Monogenea Ancyrocephalinae) parasito branquial de *Pseudocurimata gilbert* (Quoy and Gaimard, 1824) Fernandez-Yepes, 1948 (Pisces Tetragonopteridae) de La Laguna de Chascomus, Republica Argentina. Neotrópica 27: 67–78.

Suriano DM (1986) *Philocorydoras platensis* gen. n. et. sp. n. (Monogenea: Ancyrocephalidae) from *Corydoras paleatus* (Jenyns) (Pisces: Callichthyidae) in Laguna Chascomús – Republica Argentina. Helminthologia 23(4): 249–256.

Suriano DM (1997) *Palombitrema heteroancistrium* Price & Bussing, 1968 (Monogenea: Ancyrocephalidae) from *Astyanax* (*A.*) *fasciatus* (Cuvier, 1819) (Pisces: Characidae) in Chascomus Lake, Argentina: Anatomy and systematic position. Physis 53: 7–10.

Tavares-Dias M, Silva LMA, Oliveira MSB (2022) Geographic range, distribution patterns and interactions of Monogenea Van Beneden 1858, with species of native host freshwater fishes from Brazil. Revista Brasileira de Parasitologia Veterinária 31(3): e005722. https://doi.org/10.1590/s1984-29612022048

Vari RP (1989) Systematics of the Neotropical Characiform Genus *Psectrogaster* Eigenmann and Eigenmann (Pisces: Characiformes). Smithsonian Institution Press, Washington, 43 pp. https://doi.org/10.5479/si.00810282.474

Vari R, Röpke C (2013) Curimatidae. In: Queiroz LJ, Torrente-Vilara G, Ohara WM, Pires T, Zuanon JA, Doria CR (Eds) Peixes do rio Madeira. Dialeto, São Paulo, 113–140.

Vieira DH, Caramello LE, Abdallah VD, Silva RJ, Azevedo RK (2013) Community ecology of metazoan parasites of the sairú *Cyphocharax nagelii* from the Peixe River. Revista Brasileira de Parasitologia Veterinária 22(4): 611–615. https://doi.org/10.1590/S1984-29612013000400027